Hands-On Magnetic Field Projects for Classroom Demonstrations of Magnetization and Magnetic Force

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Abstract

Hands-on projects have been widely used as alternative approaches for teaching and learning of science with direct practical experience on doing to promote students' development of 21st-century skills. Here, we present an implementation of hands-on projects into teaching and learning of magnetic field topic that corresponds with indicators and core content of the curriculum of Thailand Basic Education. Notably, we demonstrated the hands-on projects of magnetization and magnetic force using low-cost materials but strived toward an understanding of science through the active and prolonged engagement of students with experiments. For the magnetization, when a current flow through a solenoid coil, magnetic material inside the coil turns to be magnet: temporary (cutter/scissors/metal-rod) or permanent (screwdriver). For the magnetic force demonstration, when a current-carrying wire is in a magnetic field produced from horseshoe shape magnet such that the direction of current flow is perpendicular to the magnetic field lines, the magnetic force moves the wire with its direction determined from Fleming's right-hand rule. We envisage that this work would be useful for helping teachers to explain and visualize the magnetic field phenomena and might facilitate future work that encourages the students to pursue inquiry-based approaches.

Keywords: Hands-on project, learning by doing, magnetic field, magnetization, magnetic force.

INTRODUCTION

Since its first conceptualization and realization (Dewey, 1938), the hands-on projects have been widely used in school classrooms and various science occasions such as science camps, science clubs, and afterschool programs (Pompea, Sparks, & Walker, 2014; Skluzacek et al., 2010; Sezenvekli, 2013; Jesús et al., 2013). Such projects are designed and developed in response to an alternative approach for teaching and learning of science with direct practical experience on doing to promote students' development of 21st-century skills, critical thinking and strong motivation to study science (Cabral, 2006; Turiman et al., 2012; Shieh, & Chang, 2014).

In comparison with biology and chemistry, physics is thought to be a more challenging subject for the students due to the reasons involving abstract concepts, physics, complex systems, limited prior knowledge or experience of the students, the realization of a finite symbol, and students' misconceptions (Setyani et al., 2017). As a result, numerous strategies targeting to improve understanding of the physics concepts by the students have been attempted and remain challenging (Stohr-Hunt, 1996). Towards this end, we adopted the hands-on projects as the alternative approach to teaching and learning of physics.

In this study, we assembled the hands-on magnetic field projects for classroom demonstrations of magnetization and magnetic force that correspond with indicators and core content of the science learning curriculum of Thailand Basic Education. We demonstrated the hands-on how to magnetize magnetic material into a magnet and how to observe the magnetic force by using low-cost materials but strived toward an understanding of science through the active and prolonged engagement of students with experiments. For the magnetization, when a current is passed through a solenoid coil, magnetic material like cutter/scissors/small metal ruler which put inside the coil turns to be magnet: temporary (cutter/scissors/metal-rod) or permanent (screwdriver). For the magnetic force demonstration, when a current-carrying wire is in a magnetic field produced from horseshoe shape magnet such that the direction of current flow is perpendicular to the magnetic field lines, the magnetic force moves the wire with its direction determined from Fleming's right-hand rule. Given the unique advantages rendered by hands-on projects, we facilitate that our demonstrations should be the guidance teaching and learning tools for helping teachers to illustrate the abstract knowledge of physics and encouraging students to gain more skills by doing.

METHODS

As the Institute for the Promotion of Teaching Science and Technology (IPST) set the indicators and core content of science learning curriculum (revised edition 2017) regarding Thailand National Core Curriculum of Basic Education in 2008 as shown in table 1

(SciCurriculum, 2560), we adopted such knowledge related to magnetization and magnetic force. We then use the Engineering Design Process as a tool to establish the hands-on projects.

Table 1. *Strand 6 Physics. Standard SC 6.3 Understand the electromagnetic force and Coulomb's law, electric field, electric potential, capacitance, electric current, Ohm's law, direct current circuit, electrical energy and power, energy conversion from renewable energy to electrical energy, magnetic field, magnetic force acting on a moving charge or a current-carrying wire, electromagnetic induction and Faraday's law, alternating current electricity, and electromagnetic waves and communication; Adopt such knowledge for the use.*

Grade	Indicators	Core learning content
12	1.3 Observe and explain an occurrence of magnetic field due to a current flow through a solenoid.	Passing a current through a solenoid, a magnetic field occurs.
	2.1 Explain the magnetic force that acts on a current-carrying wire in the uniform magnetic field.	When a current-carrying wire is in a magnetic field, the wire finds itself under the magnetic force with its direction determined from the Fleming's right-hand rule.

RESULTS AND DISCUSSION

In this section, we presented an implementation of hands-on projects into teaching and learning of the magnetic field topic. In particular, we showed the classroom demonstrations of magnetization and magnetic force with low-cost materials but strived toward an understanding of science through the active and prolonged engagement of students with experiments.

Classroom Demonstration of Magnetization

In the classroom, the students were asked to construct a magnet using simple tools, materials, and other supplies such as cutters, scissors, metal rods, screwdrivers, dry cells, wires, paper clips, plastic tapes, etc. The results shown in figure 1 displayed this project task from students. By passing a direct current through a coil of wire, the magnetic materials inside the coil were magnetized and became the magnet; notably, they were temporary and could be switched on and off by controlling the electricity (Figure 1 (a)).

Furthermore, one of these magnetic materials, like a screwdriver, exhibited the permanent magnet as it could retain its magnetism after magnetization (Figure 1 (b)).

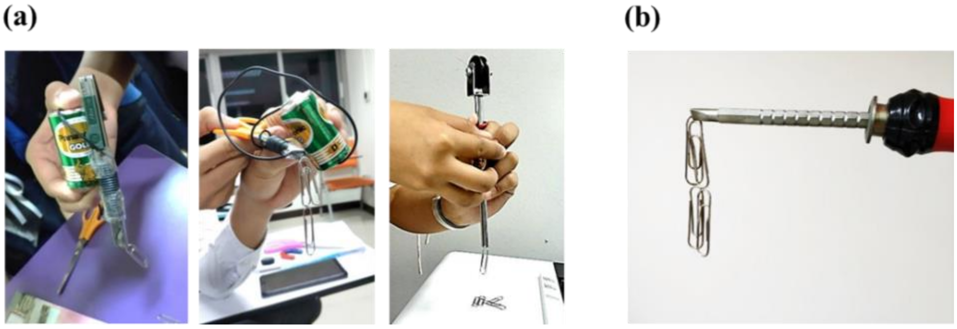

Figure 1. A schematic of the setup used for classroom demonstration of magnetization, together with its corresponding results. (a) Temporary magnet could be turn on and off by controlling the electricity. (b) Permanent magnet continually attracted the objects after magnetization.

Based on this hands-on project, the content knowledge of magnetization that corresponds with indicators and core content of the curriculum of Thailand Basic Education was further provided to the students, as shown in figure 2. Passing a direct current through a long coil or solenoid made up of several turns of conducting wire causes a magnetic field with its direction determined from the right-hand grip rule: screw fingers around the coil in the course of the current, thumb indicates the north pole (Figure 2 (a)). If placing a magnetic material inside the coil, the magnetic dipoles or tiny magnets within such content will experience the magnetic field by turning and pointing themselves toward the same direction of the magnetic field (Figure 2 (b)). Consequently, the magnetic material becomes the magnet.

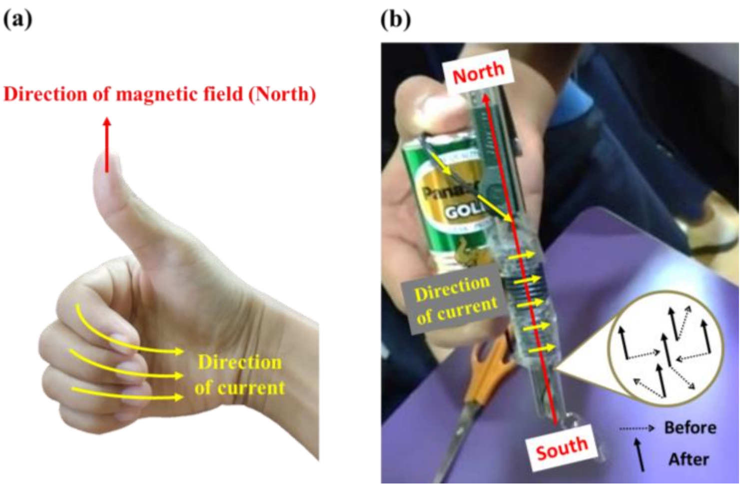

Figure 2. *Underlining principle of magnetization. (a) Right-hand grip rule to determine the direction of magnetic field on the axis of circular coil carrying current. (b) In the vicinity of magnetic field, the dipoles of material were aligned in the same direction thereof.*

Also, the students' ability in science observation could be further developed through the employment of minds-on questions, i.e., predict stationaries/tools/machinery used as the core in which exhibit the temporary or permanent magnets, what would be happened if the strength of the current is increased? What would be repeated if the number of turns of the coil is increased? Etc.

Classroom Demonstration of Magnetic Force

For this task, the students were further encouraged to demonstrate the hands-on project related to a force on a current-carrying wire in an external magnetic field. Figure 3 displayed a schematic of the setup used for this project, together with its corresponding results. When the current-carrying wire was in the magnetic field produced from horseshoe shape magnet such that the direction of current flow was perpendicular to the magnetic field lines (figure 3 (a)), the wire found itself under the magnetic force: it moved toward inside the magnet when the north pole located at the bottom (Figure 3 (b)) whereas it ran out of the magnet when the north pole was at the top (Figure 3 (c)). We noted that images of no/with the current in each section were captured at the consecutive time series with a video camera operated at 30 interlaced frames per second.

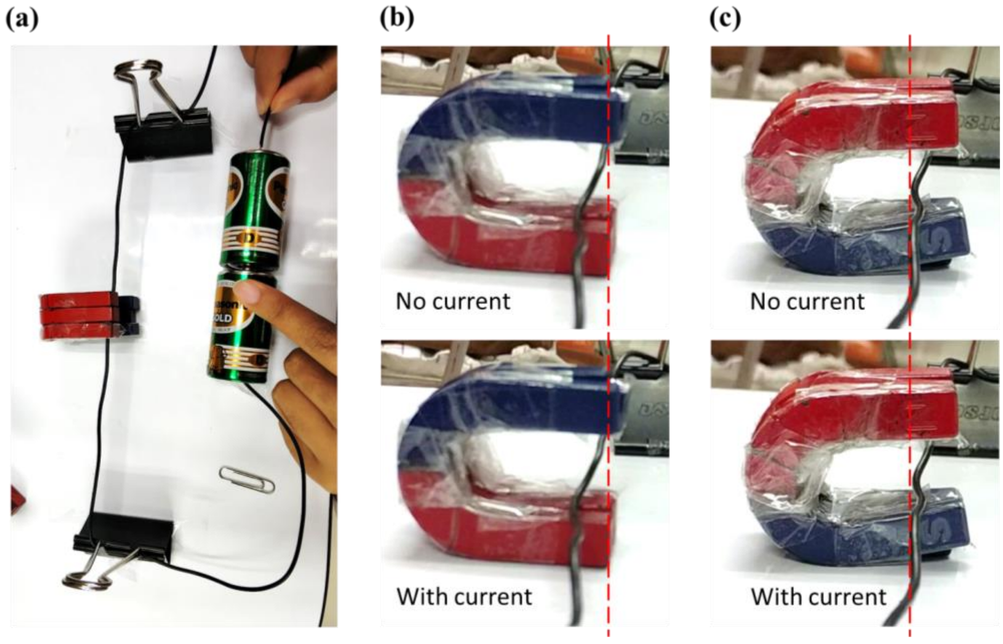

Figure 3. A schematic of the setup used for classroom demonstration of magnetic force, together with its corresponding results. (a) Experimental setup. (b) Magnetic force led the wire to move inside. (c) In contrast, magnetic force led the wire to move outside after reversing the horseshoe shape magnet.

Based on this activity, the content knowledge of magnetic force according to the indicators and core content of the curriculum of Thailand Basic Education was given to the students as shown in figure 4: The current-carrying wire in the magnetic field experiences a force with its direction determined from Fleming's right-hand rule. By holding the thumb, forefinger, and middle finger in mutually perpendicular directions, the thumb indicates the force direction while forefinger shows the direction of current and middle finger points toward the direction of the magnetic field (Figure 4 (a)). Accordingly, through the reversion of the direction of the magnetic field, the wire moves in the opposite direction (Figure 4 (b)).

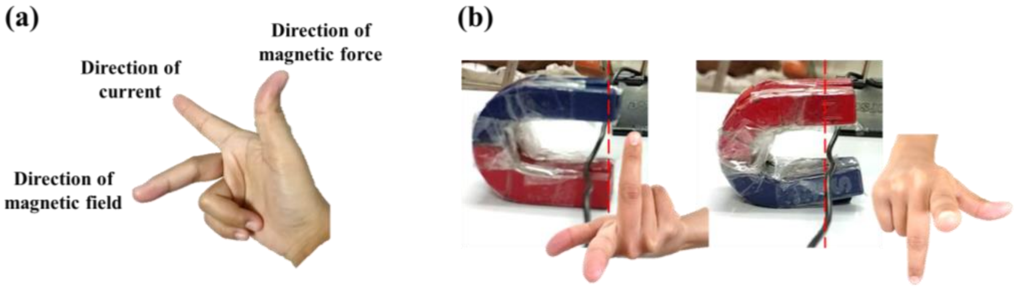

Figure 4. *Underlining principle of magnetic force. (a) Fleming's right-hand rule to illustrate the magnetic force, current, and magnetic field (b) Wire moved in opposite direction when reversing the direction of magnetic field.*

Likewise, to stimulate the students' ability in scientific observation, the minds-on questions could be further given to students, i.e., predict the movement of wire when the direction of current is reversed, what would be happened if the strength of the current is increased? What would be happened if the strength of the magnetic field is increased? Etc.

CONCLUSIONS

We presented the classroom demonstrations of magnetization and magnetic force enabled with corresponding physics knowledge using pure, flawless, and instructive hands-on activities to facilitate their potential for boosting the understanding of the abstract content knowledge and also cultivating the direct practical experience on doing. The demonstrations proposed from this work are very economical but give the students valuable insight into experimental methods. In specific, they can be useful for helping teachers to explain and visualize the physics phenomena by the magnetic field and might facilitate future work that encourages the students to experiment, to think, and to pursue inquiry-based approaches.

RECOMMENDATIONS

As our program is designed and developed toward promoting students or schoolteachers to intimate learning and teaching science through the use of materials with friendly price and locally available but provided a high description in science (Author), we seek ways of helping them integrate the application of magnetic field into classroom demonstrations comprising magnetization and magnetic force. The price of magnetization setup in Thai Baht is about 52 (included stationary of 15, wire of 10, Battery of 25, and Metal Clip of 2 for five pieces) whereas that of magnetic force setup is 172 (included Horseshoe-Shape-Magnet of 100 for three parts, wire of 10, Clip-50-mm of 12 for two pieces, and Battery of 50 for two pieces). We do hope that these activities not only reflected the enthusiasm for learning and teaching in science but also would be suitable for the Opportunity Expansion School. Given the advantage of the hands-on magnetic field projects with low-cost materials, we are planning to spread these undertakings to the Opportunity Expansion School where we are responsible for.

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